sPHENIX

S&T Review

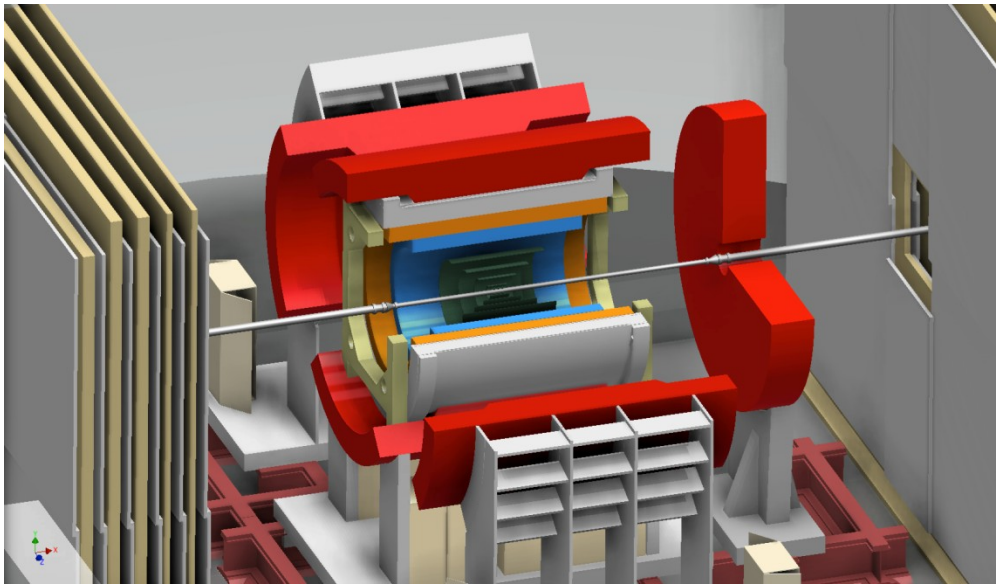
BNL

Sept 16-18, 2014

Outline

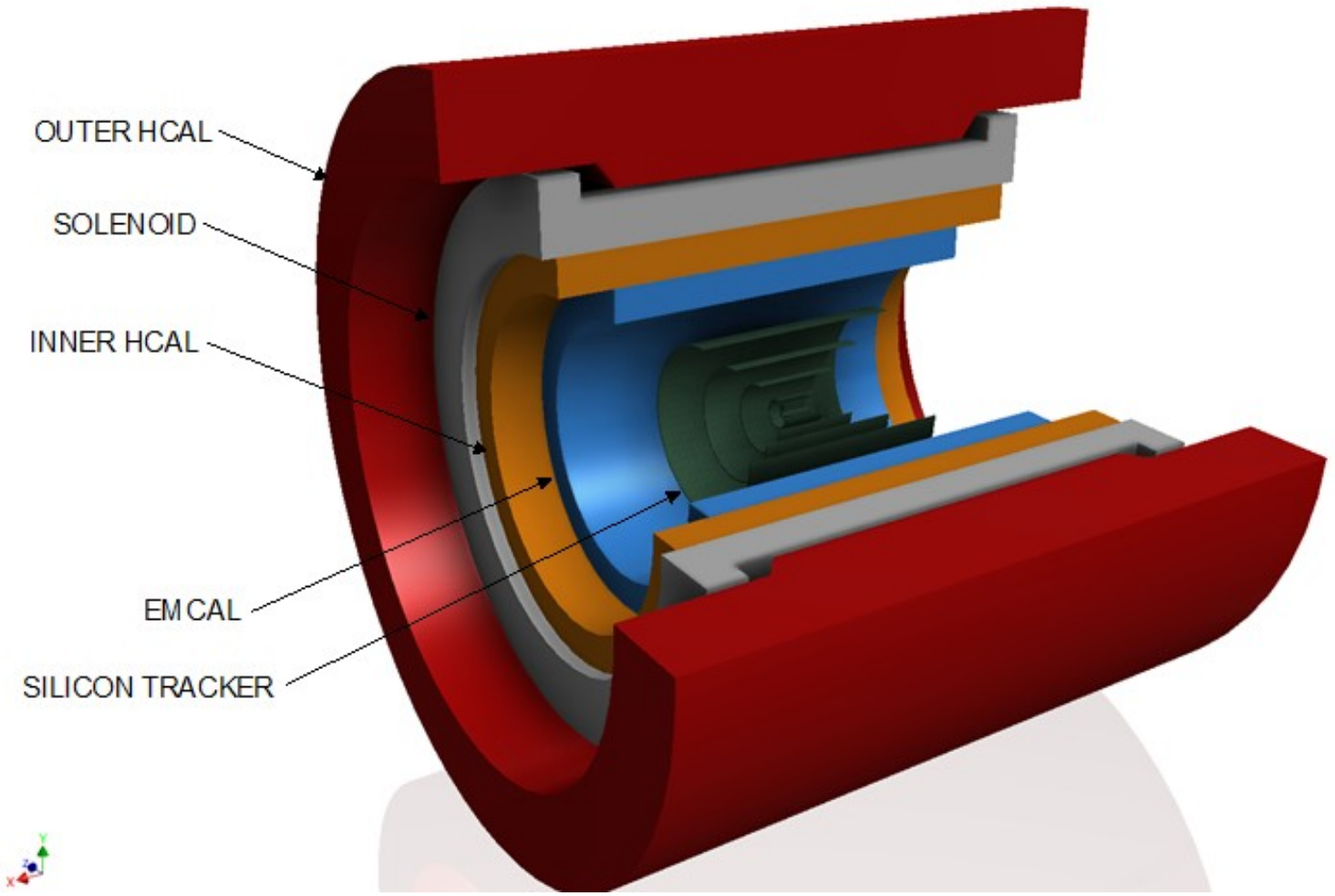
- Overview
- Reference Design
- Science Review and Recent Progress on Simulations
- Design Progress
- R&D Status
- Project Management
- Summary

What is sPHENIX?

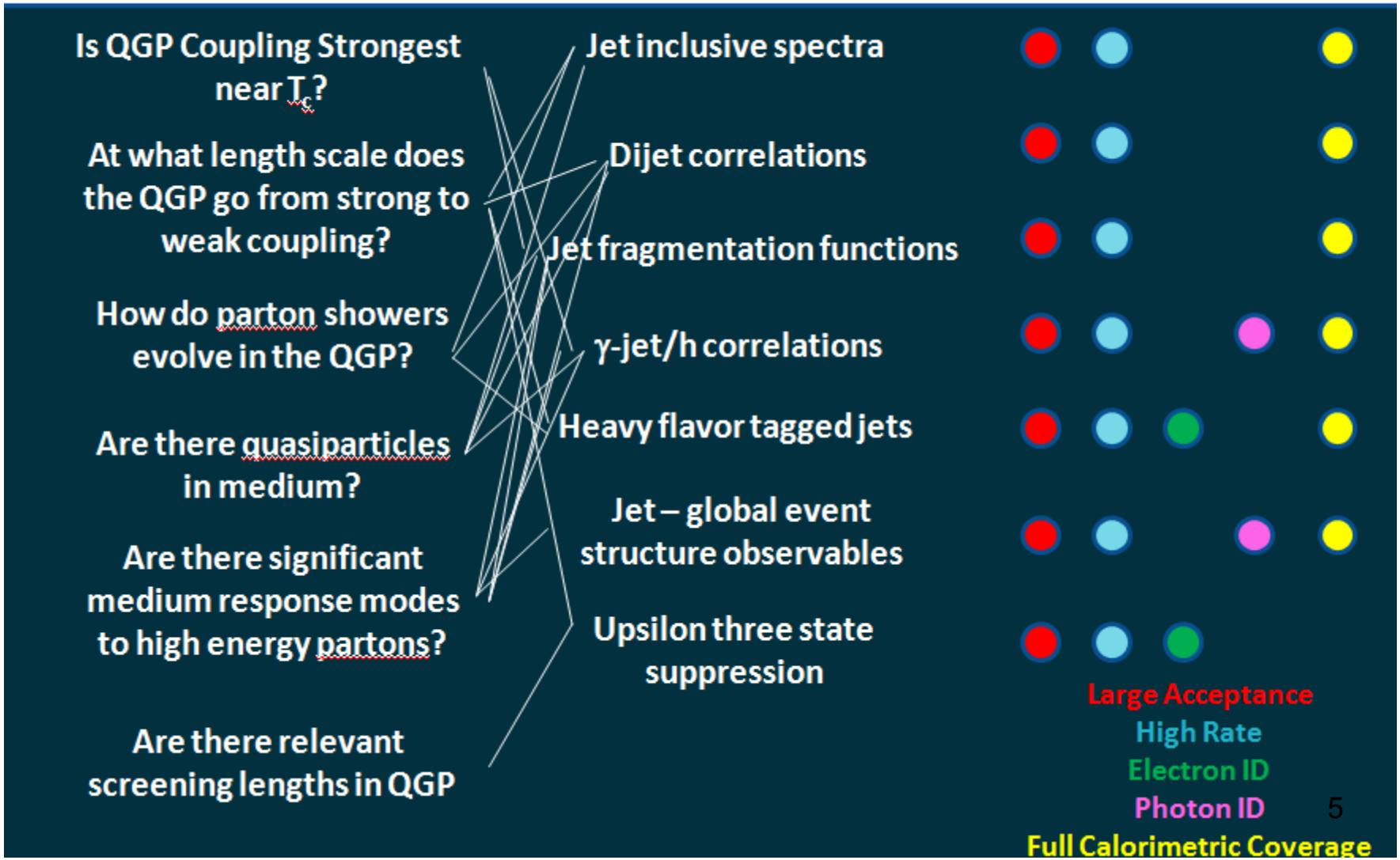


- **sPHENIX is a major upgrade to PHENIX. It is a new, large-acceptance, high-rate detector for HI physics to be built in the PHENIX hall.**
- **It will be optimized to measure jet and heavy quark physics by incorporating a vertex tracker, full EM and Hadronic calorimeter coverage at $|\eta| < 1.1$, and a 1.5 T solenoidal magnetic field.**
- **It will utilize most of the infrastructure already existing in the PHENIX detector complex and the SC-magnet previously used by the BaBar experiment at SLAC.**

Model of sPHENIX Detector Plus Magnet



Mapping Physics Questions onto sPHENIX Observables



What Drives the Design We Have Chosen?

- **The Upsilon measurements drive tracking and EMCal performance specs**
- **Jets drive the HCal performance specs**
- **Both together drive acceptance, data rate and triggering**
- **Other key observables are enabled by satisfying those requirements**

sPHENIX Ingredients

- Uniform acceptance $-1<\eta<1$ and $0<\varphi<2\pi$
- Superconducting solenoid enabling high resolution tracking
- Re-use of PHENIX silicon vertex detector plus additional silicon tracking layers.
- Hadronic calorimeter doubling as flux return
- Compact electromagnetic calorimeter to allowing fine segmentation at a small radius
- Solid state photodetectors that work in a magnetic field, have low cost, do not require high voltage
- Common readout electronics in the calorimeters

sPHENIX is Built on the Foundation of PHENIX

sPHENIX is a major upgrade to the PHENIX experiment, built on infrastructure assembled over nearly twenty years

- **Mechanical: rails, crane, shield wall, cooling**
- **Electrical: power distribution, grounding**
- **Safety systems**
- **Data acquisition computing and networking**
- **Work areas**

sPHENIX SC Magnet

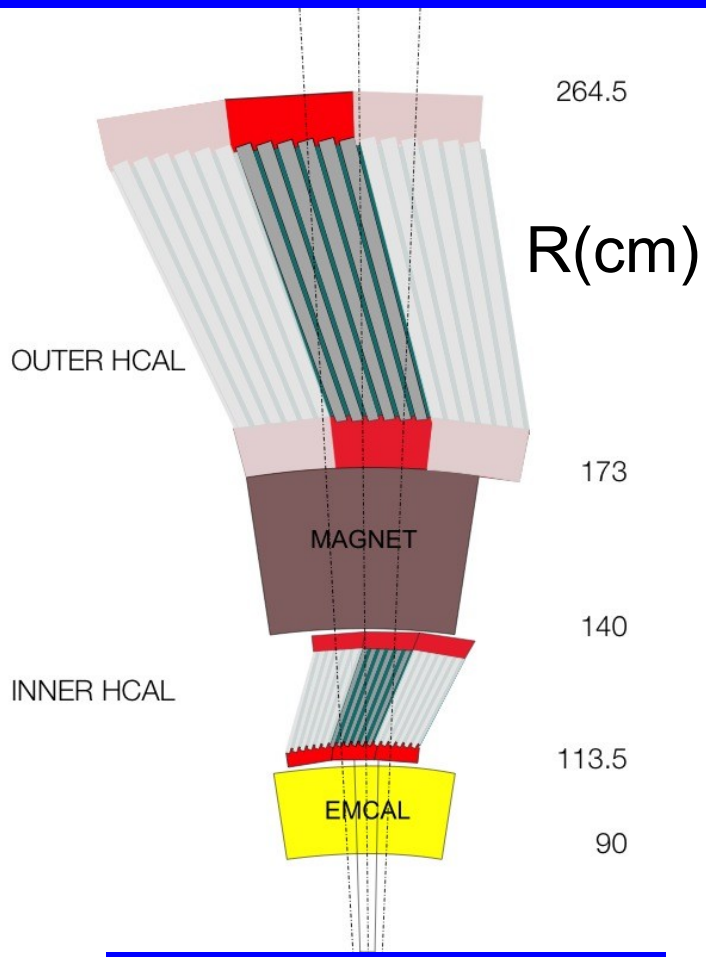
The sPHENIX solenoid will be the former BaBar solenoid

- **1.5 T central field**
- **Cryostat 140 cm < r < 173 cm**
- **384 cm length covers -1.1 < η < 1.1**
- **Considerable additional equipment also available**
  - **Power supplies, dump resistor, quench protection**
  - **Valve box and cryogenic paraphernalia**
  - **Lifting fixtures**
- **Manufactured by Ansaldo 1997, still in excellent condition**
- **Transfer of ownership to BNL approved by DOE**

BaBar Solenoid at SLAC circa 1997

Calorimeter reference design

- **EMCAL Tungsten-scintillating fiber**
  - **$\Delta\eta \times \Delta\varphi \approx 0.025 \times 0.025$**
  - **96 x 256 readout channels**
  - **EMCal $\Delta E/E < 15\%/\sqrt{E}$ (single particle)**
- **HCAL Steel and scintillating tiles with wavelength shifting fiber**
  - **2 Longitudinal segments.**
  - **An Inner HCal inside the solenoid.**
  - **An Outer HCal outside the solenoid.**
  - **$\Delta\eta \times \Delta\varphi \approx 0.1 \times 0.1$**
  - **2 x 24 x 64 readout channels**
  - **HCal $\Delta E/E < 100\%/\sqrt{E}$ (single particle)**
- **Readout Solid state photodetectors (silicon photomultipliers, avalanche photodiodes)**



- **Outer HCAL ≈4λ_I**
- **Magnet ≈1X_0**
- **Inner HCAL ≈1λ_I**
- **EMCAL ≈18X_0≈1λ_I**

EMCal design choices

- **EIC R&D and SBIR has supported development of compact tungsten-scintillator calorimeters**
- **Several calorimeter prototypes constructed and beam tested**
- **Light production verified to be adequate for SiPM readout**
- **Manufacturing and operational experience**
- **Tungsten SPACAL has advantages that make it the design of choice**
  - **Simplicity of manufacture**
  - **Good resolution in beam test**
  - **Projective in ϕ, symmetric**

EMCal Spacal Design

Choice of Technology, EM section.

Parameters:

Final Density - 10.17 g/cm^3,
X_0 ~ 7 mm, R_m ~ 2.3 cm,
S_f -2% (electrons),
Sc. Fibers -SCSF78
Ø 0.47 mm
Spacing 1 mm center-to-center.

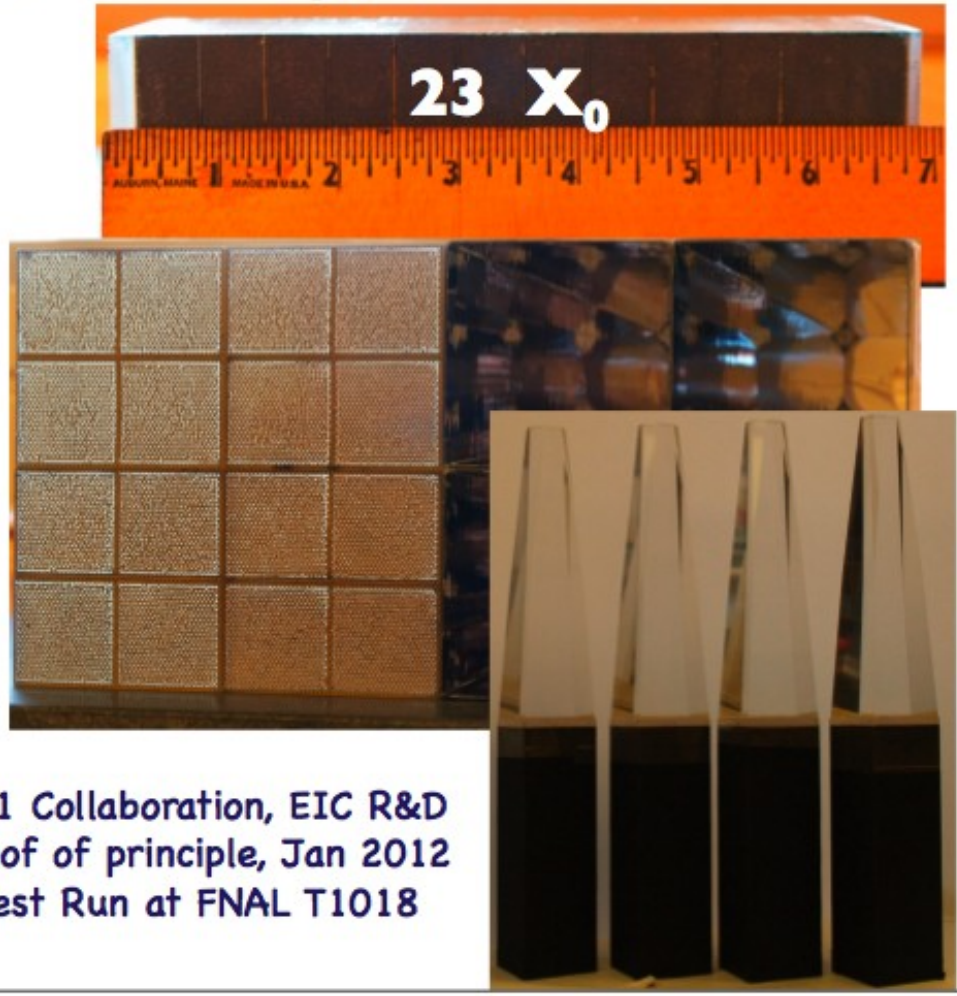
Supermodule 2x2 towers.

Details:
Dimensions 16.6 × 5.33 ×5.33 cm^3
Weight of supermodules (4567, 4651, 4627,4630 g.)
Number of fibers -3120

Resolution ~12%/√E

Light yield 2000 p.e./GeV

SiPM Readout Possible.

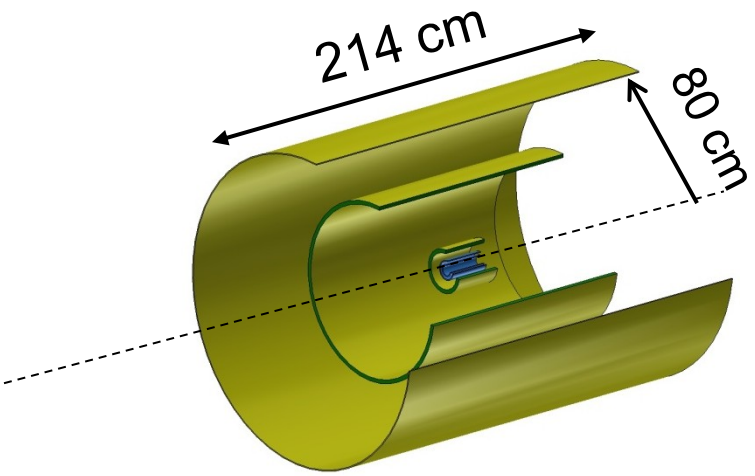


RD1 Collaboration, EIC R&D
Proof of principle, Jan 2012
Test Run at FNAL T1018

Giessen, CALOR2014,. April 10 2014

Slide from Oleg Tsai, CALOR2014

Silicon Tracker Reference Design

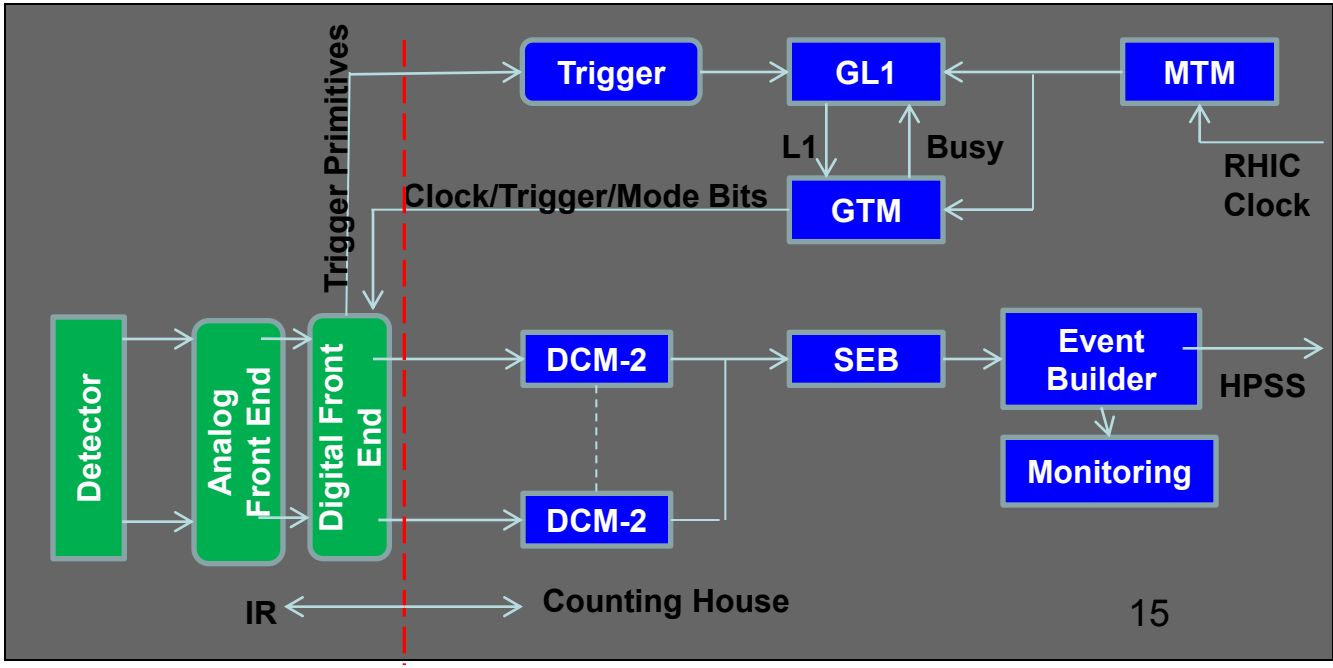


Two pixel layers
Two pairs of stereo strip layers
One Outer strip layer

Layer	Radius (cm)	Length in z (cm)	Type	Pixel/strip dimensions (μm x mm)	X resolution (microns)	Z resolution (mm)	Thickness (% X/X_0)
B1	2.7	22	Pixel	50 x 0.425	15	0.12	1.3
B2	4.6	22	Pixel	50 x 0.425	15	0.12	1.3
S0a	9.5	25.4	strip	60 x 8	18	2.3	2.0
S0b	10.5	28.1	pattern recognition	240 x 2	70	0.58	
S1a	44.5	118.9	strip	60 x 8	18	2.3	2.0
S1b	45.5	121.6	pattern recognition	240 x 2	70	0.58	
S2	80	213.7	strip	60 x 8	18	2.3	2.0

sPHENIX FEE, DAQ and Trigger Scheme

- Based on PHENIX experience
- Maintain as much of the PHENIX DAQ as reasonable
  - Event Builder, DCM-II
  - Slow control infrastructure
  - Monitoring and data logging infrastructure
- Similar compact design for EMCal and HCal Readout
  - Sensor (SiPM)
  - Analog front end on the detector
  - Digitization in the IR, digital data to counting house
- Simple, reliable front end electronics on the detector, minimizing connections
- No ASIC development



DOE-charged Science Review of sPHENIX

A DOE-charged science review of sPHENIX was held July 1-2 at BNL.

The Review report is not yet final but generally the committee felt that the proposed sPHENIX physics program was compelling. We were encouraged to continue studies to maximize the sPHENIX physics potential and strengthen the science case.

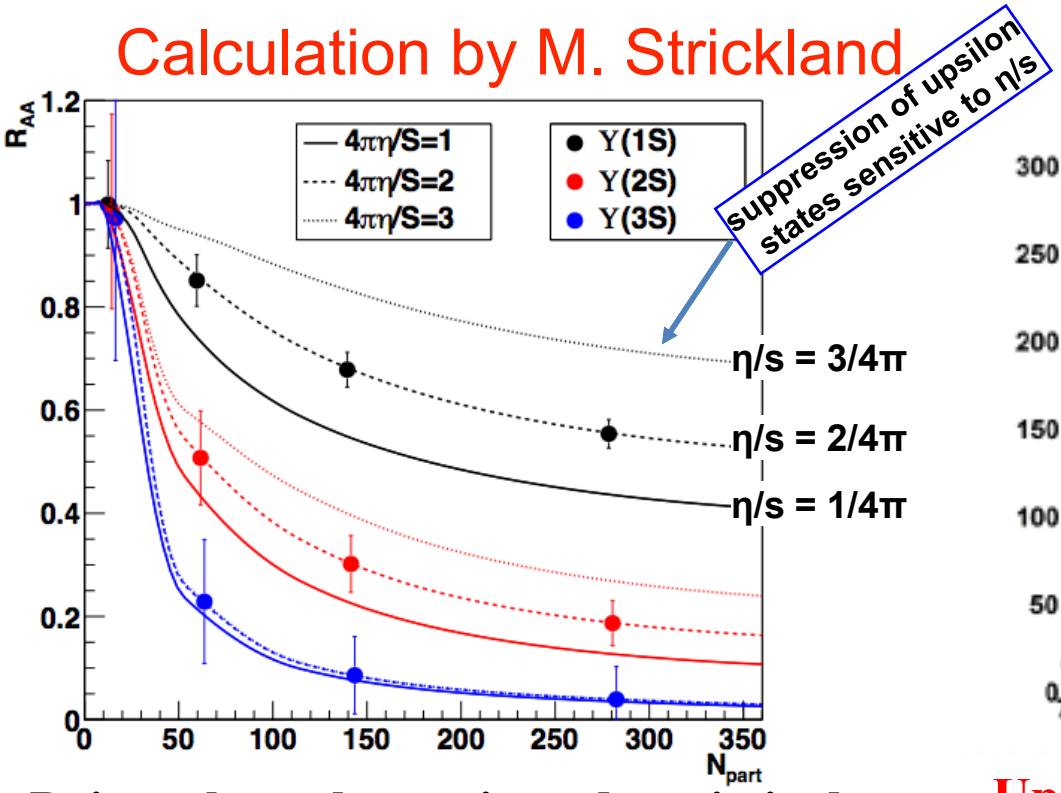
A revised sPHENIX proposal will be submitted to DOE in early Nov 2014 that will address:

- **Ways to improve upsilon resolution and statistics**
- **sPHENIX capabilities to measure an unbiased sample of heavy-flavor tagged jets**
- **Prospects of improving PHENIX DAQ rates to take advantage of the likely improvements in RHIC luminosities beyond those projected in the existing proposal**
- **Potential benefits to modest instrumentation at forward rapidities to increase scientific reach.**

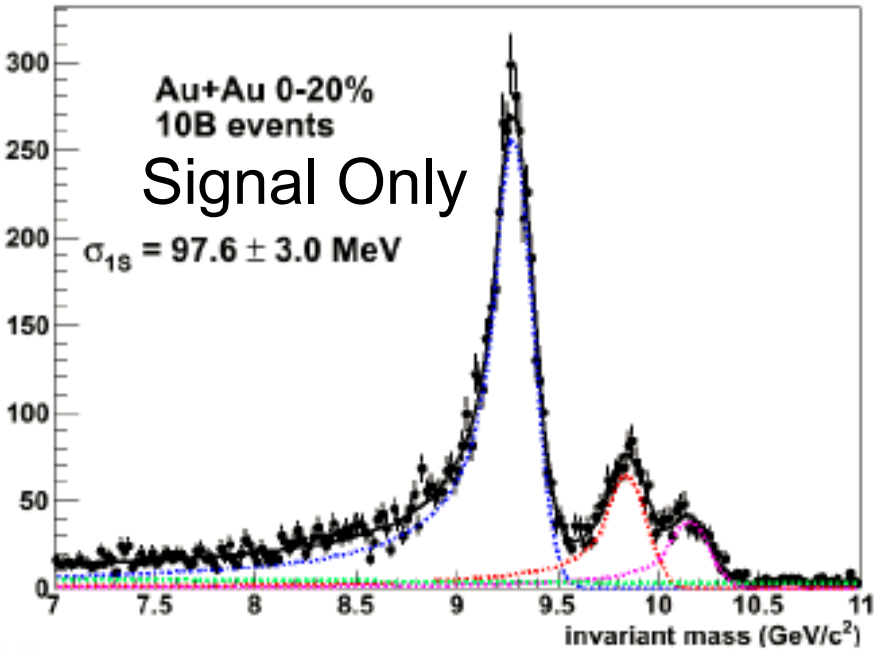
Simulation Results Since the July Review: Upsilon Physics

The committee suggested that we reevaluate tracking configuration and aim for 100 MeV/c^2 resolution.

Calculation by M. Strickland



Points show the projected statistical accuracy, including background.



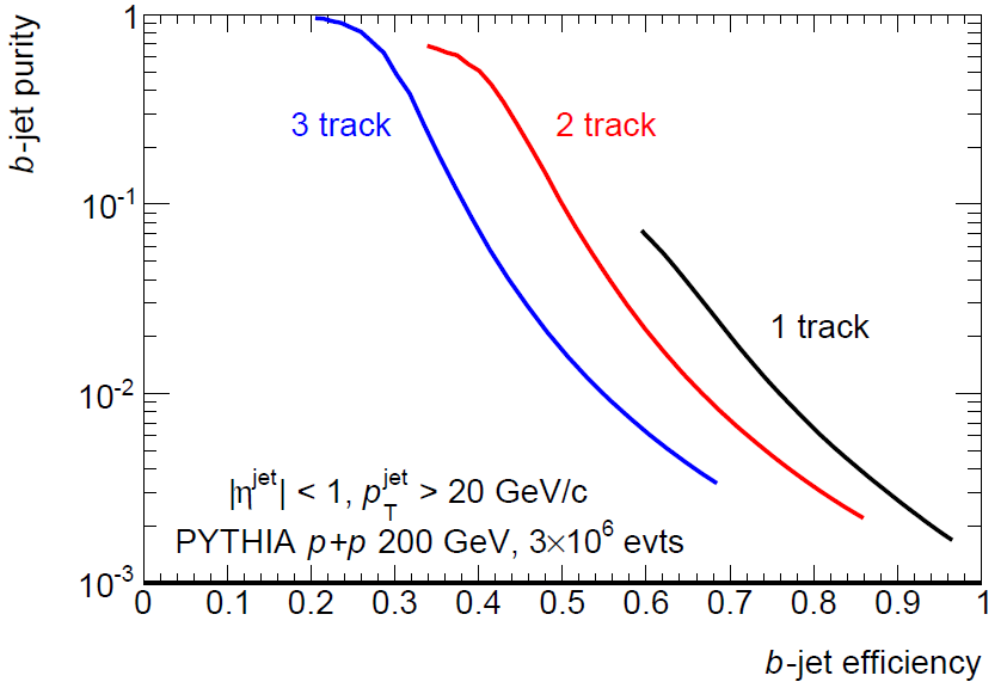
Updated tracking configuration looks very promising in terms of momentum resolution, efficiency, and purity.

Working to finalize new reference design and specs in the next three weeks.

Simulation Results Since the July Review: B-jet Tagging

The committee recommended that we explore the potential for sPHENIX to do B-jet tagging. The team is working very hard to evaluate the full performance of b-tagging and D meson reconstruction.

Track counting: jet with at least *N* tracks that don't point to primary vertex



40-50% purity and 30-50% efficiency achievable by selecting multiple "off-vertex" tracks

Variety of proven techniques: soft lepton tagging, track counting, secondary vertex reconstruction

Initial parameterized studies for p+p look very promising (good region of b-jet purity versus efficiency)

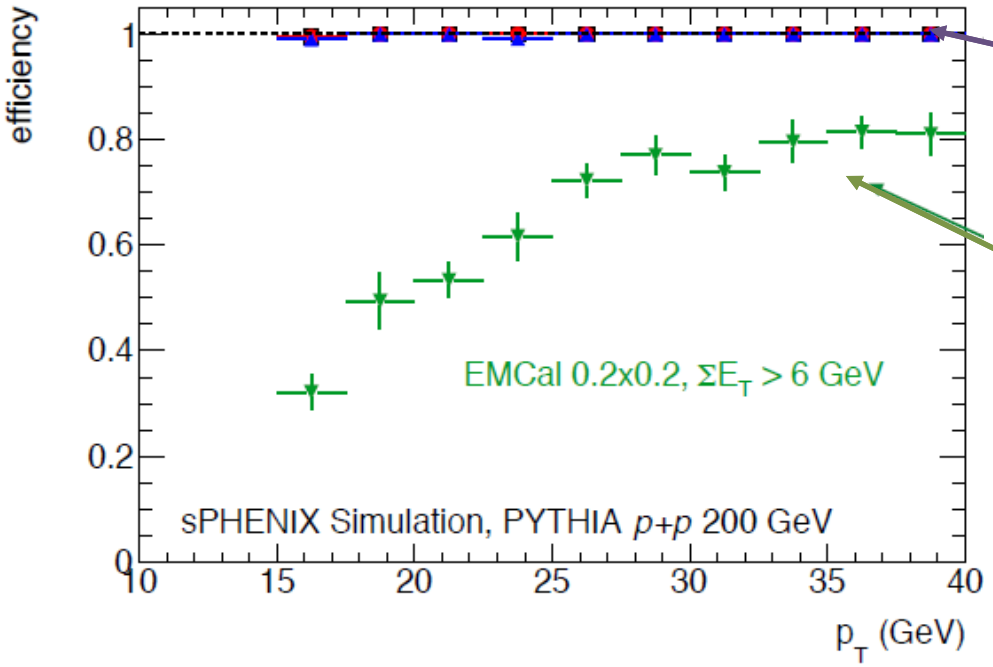
Pushing to full GEANT4 simulations and occupancy implications.

Simulation Results Since the July Review: Optimizing Rates and Triggers

C-AD had updated its official luminosity projections. Expect additional factor of two in p+p and Au+Au. sPHENIX DAQ rate appears possible up to 15 kHz.

Implies in 25 week Au+Au run, one can sample 1/2 *trillion* events for jets and direct photons.

Full simulations of p+p triggering complete and looks very good.



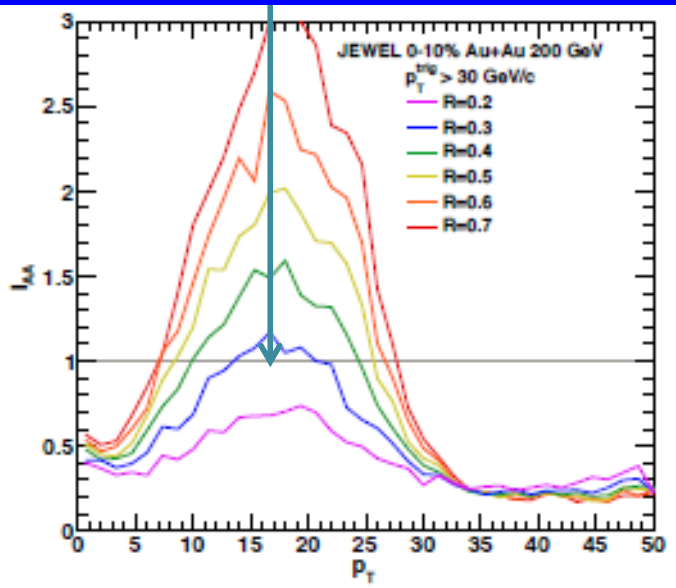
0.8 x 0.8 EMCal+HCal, very efficient no observable p_T dependence

0.2 x 0.2 EMCal (approx. STAR trigger) lower efficiency, slower turn-on, p_T dependence may introduce bias between gluon jets (more dominant at low p_T) and quark jets (more dominant at higher p_T)

p+p triggering for unbiased jet sample, looks to have very good rejection and high efficiency.

Simulation Results Since the July Review: Discriminating Jet Observables (incl Large R jets)

RHIC



JEWEL calculation

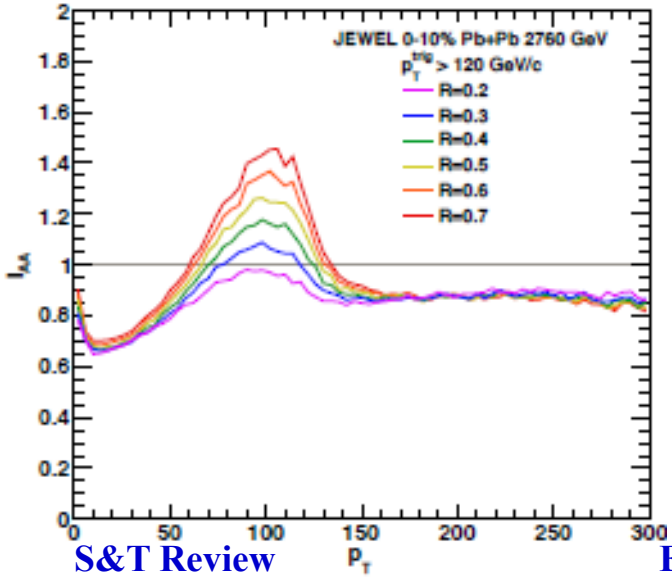
Trigger Jet R=0.2 or hadron and look on away side for energy within R = 0.2-0.7

Where is the lost energy? Larger angles, completely thermalized, how much transferred to objects in medium.

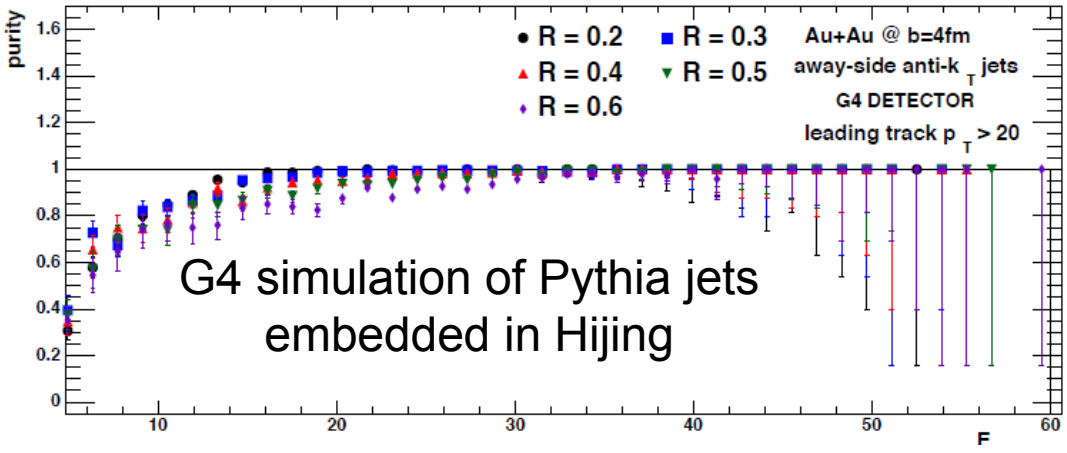
Huge R dependence at RHIC (600%)

Full sPHENIX GEANT4 Simulations look good for jet purity.

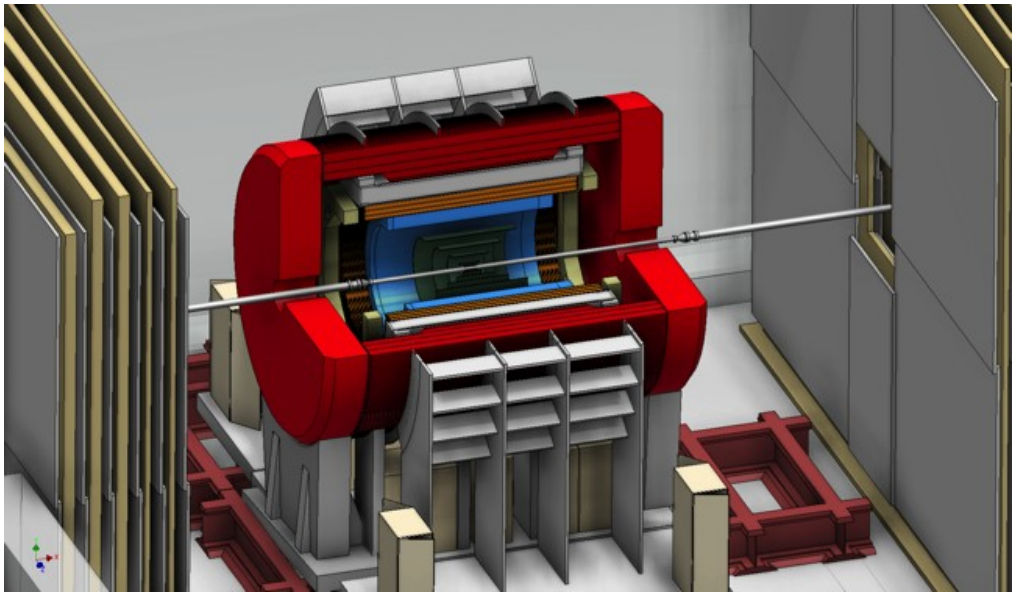
LHC

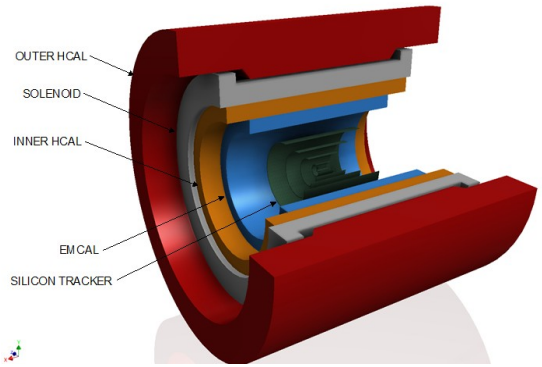


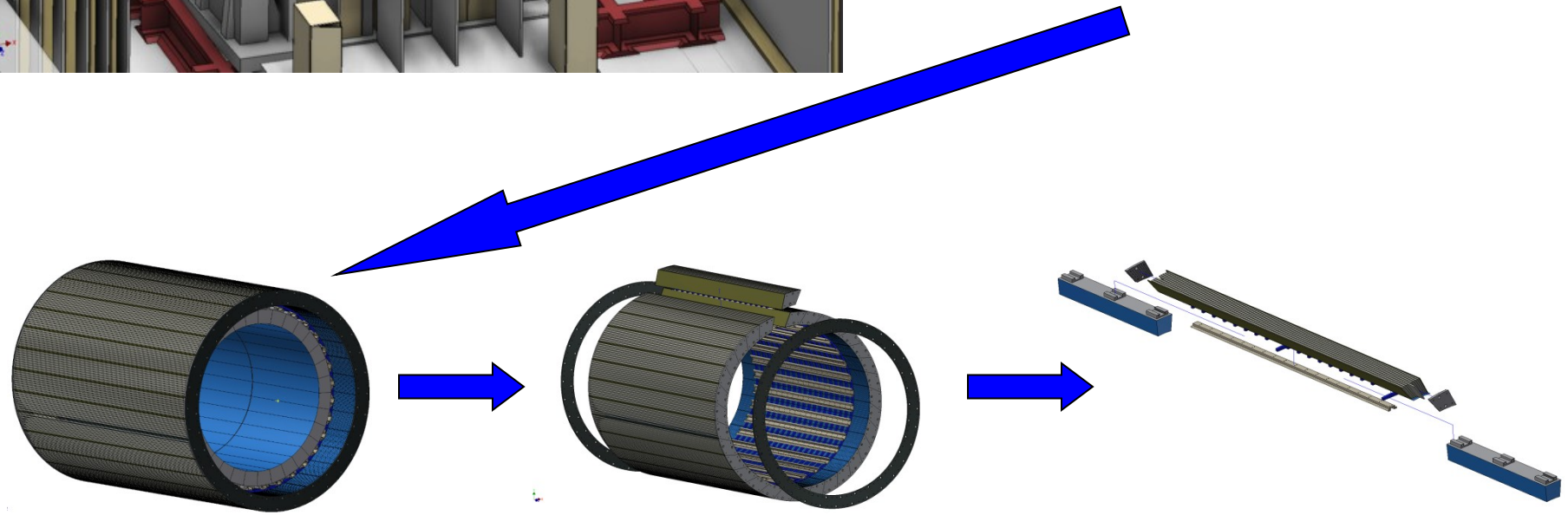
Given a high pT hadron trigger, the away side jet can be found cleanly even for very large R



sPHENIX Design Progress



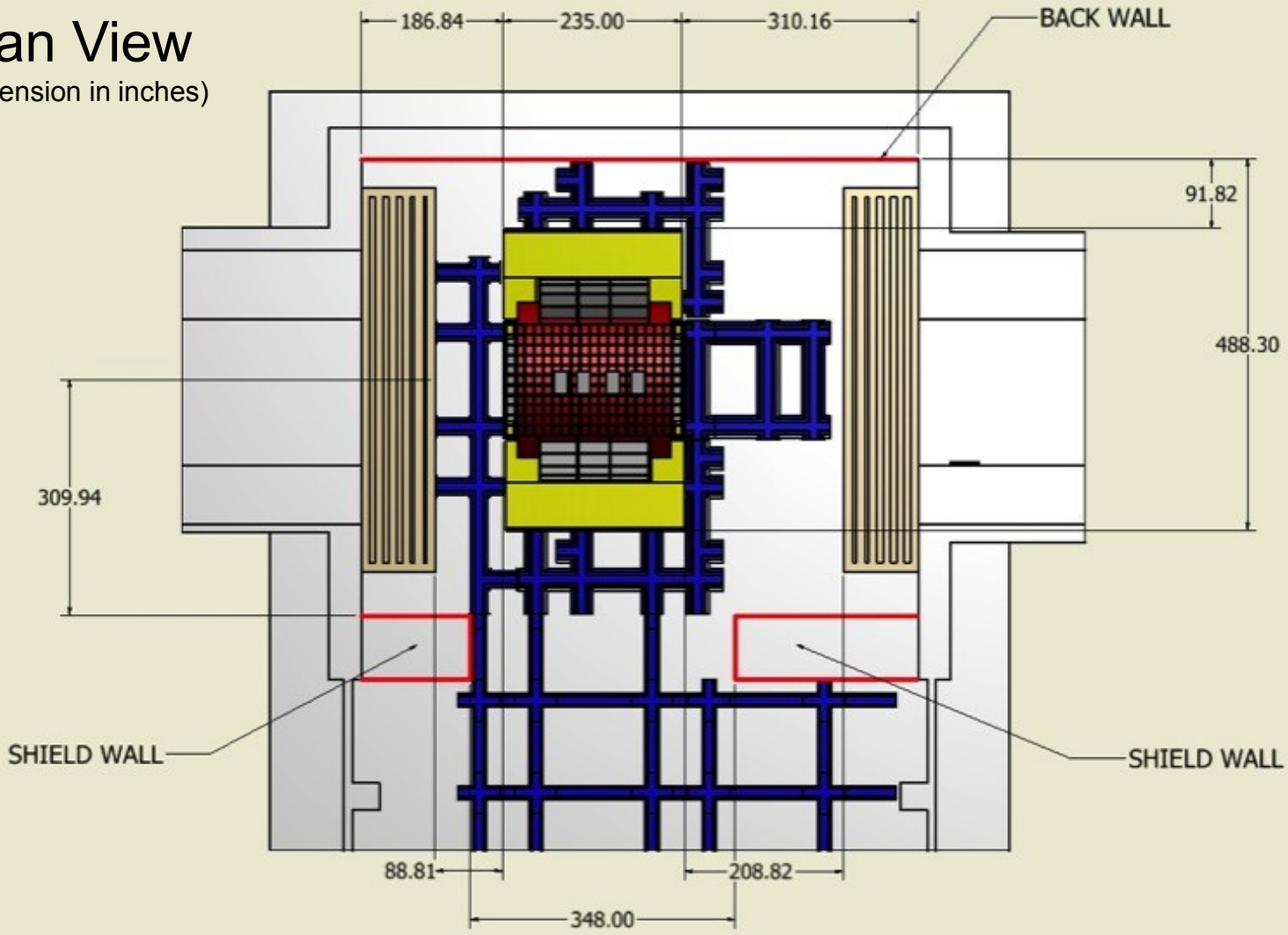




sPHENIX In the 1008 Hall

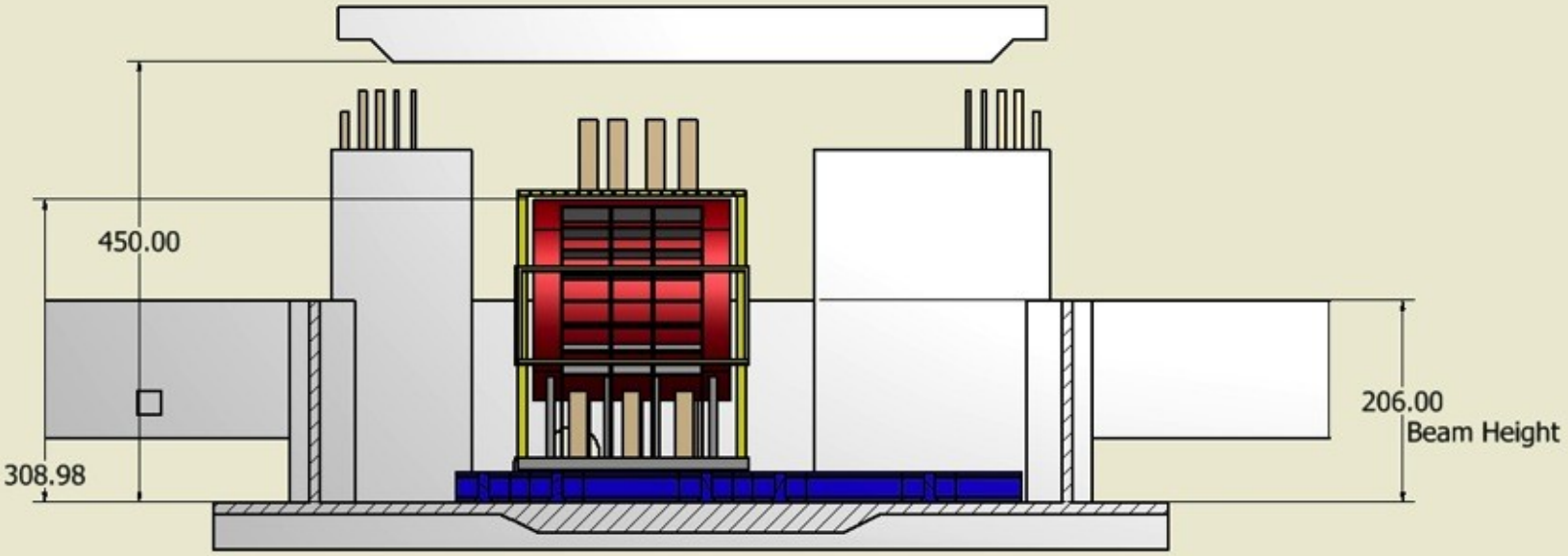
Plan View

(dimension in inches)

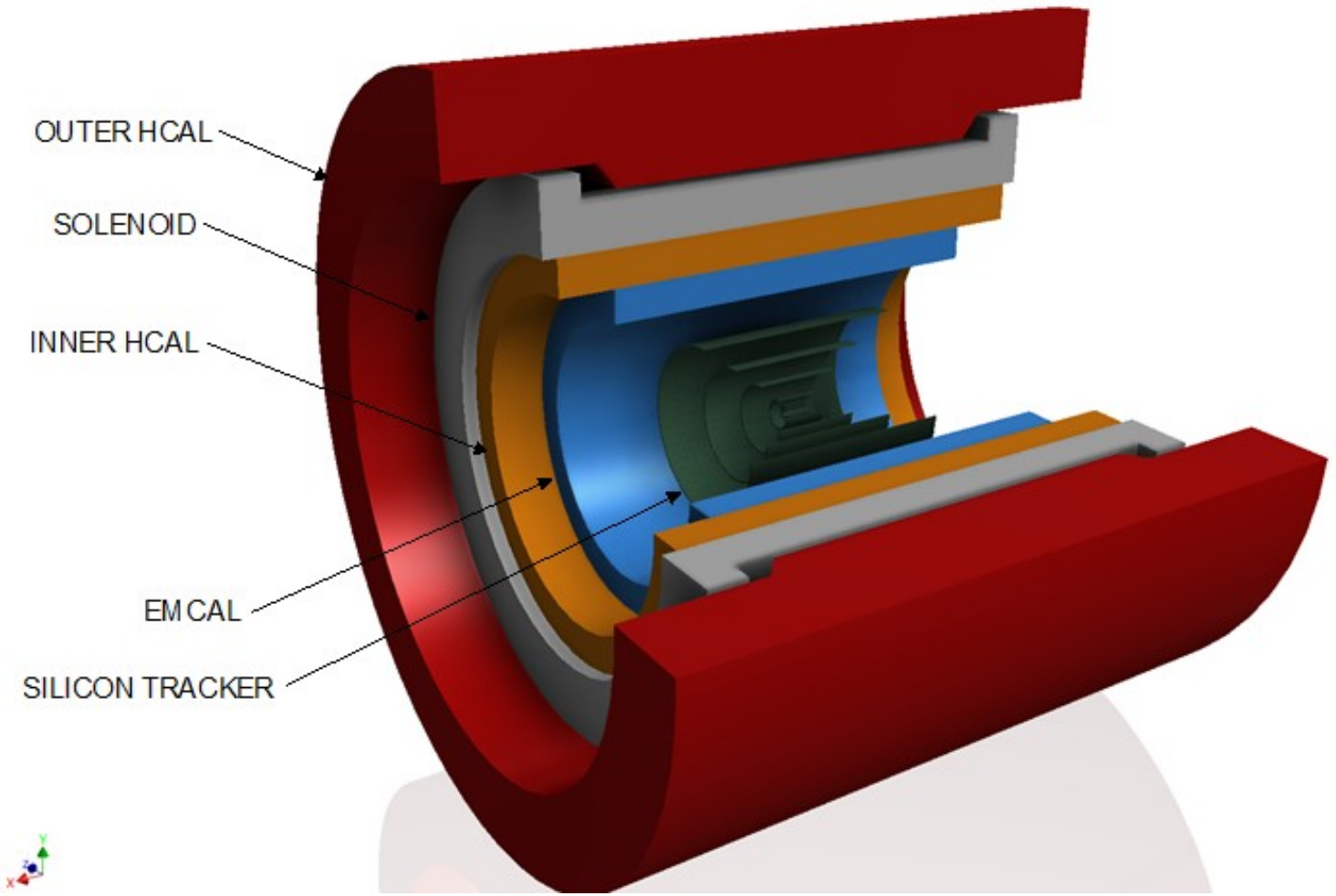


Elevation View

(dimension in inches)

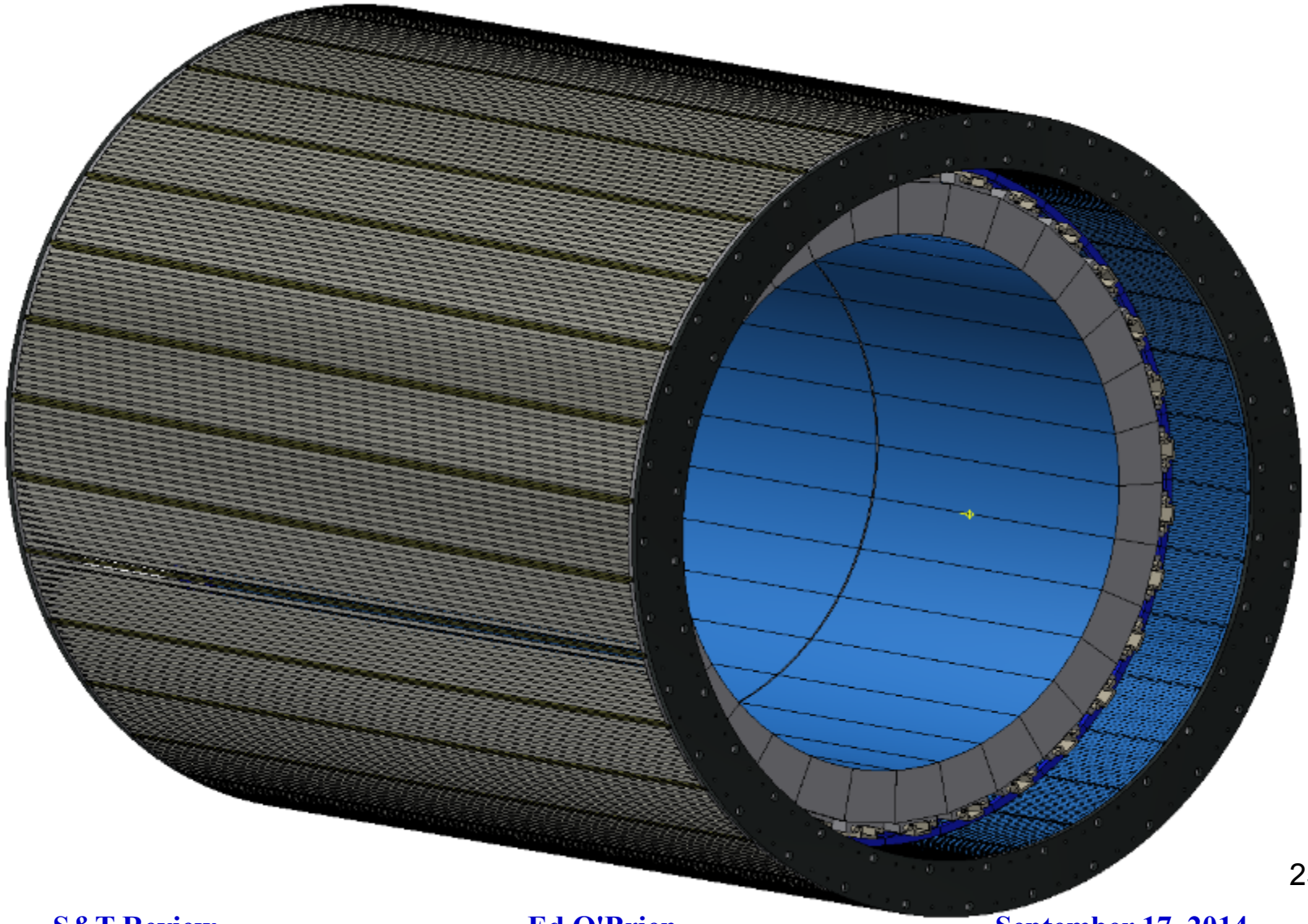


sPHENIX Central Barrel



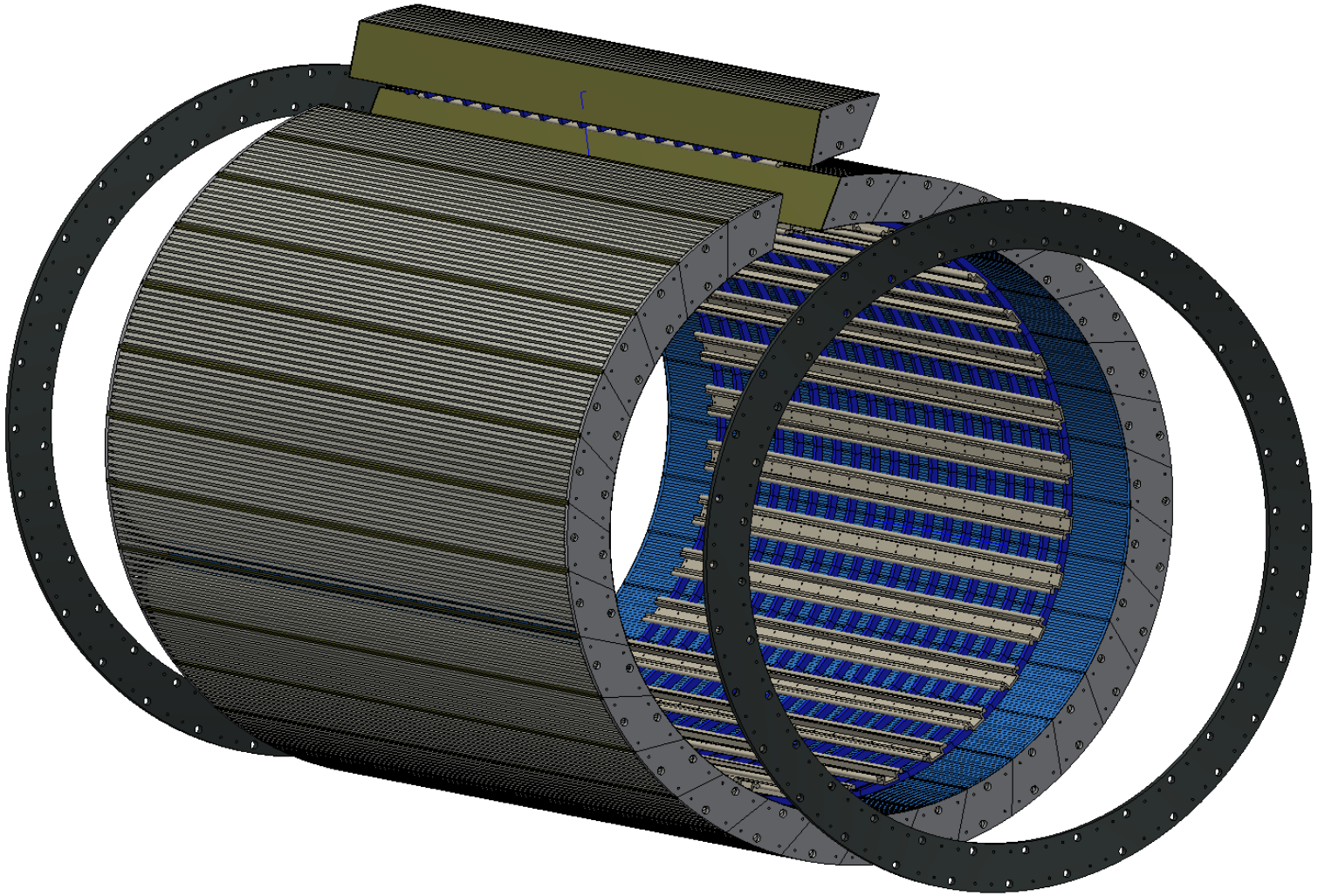
Inner HCal Supporting the EMCal

Internal Support Concept



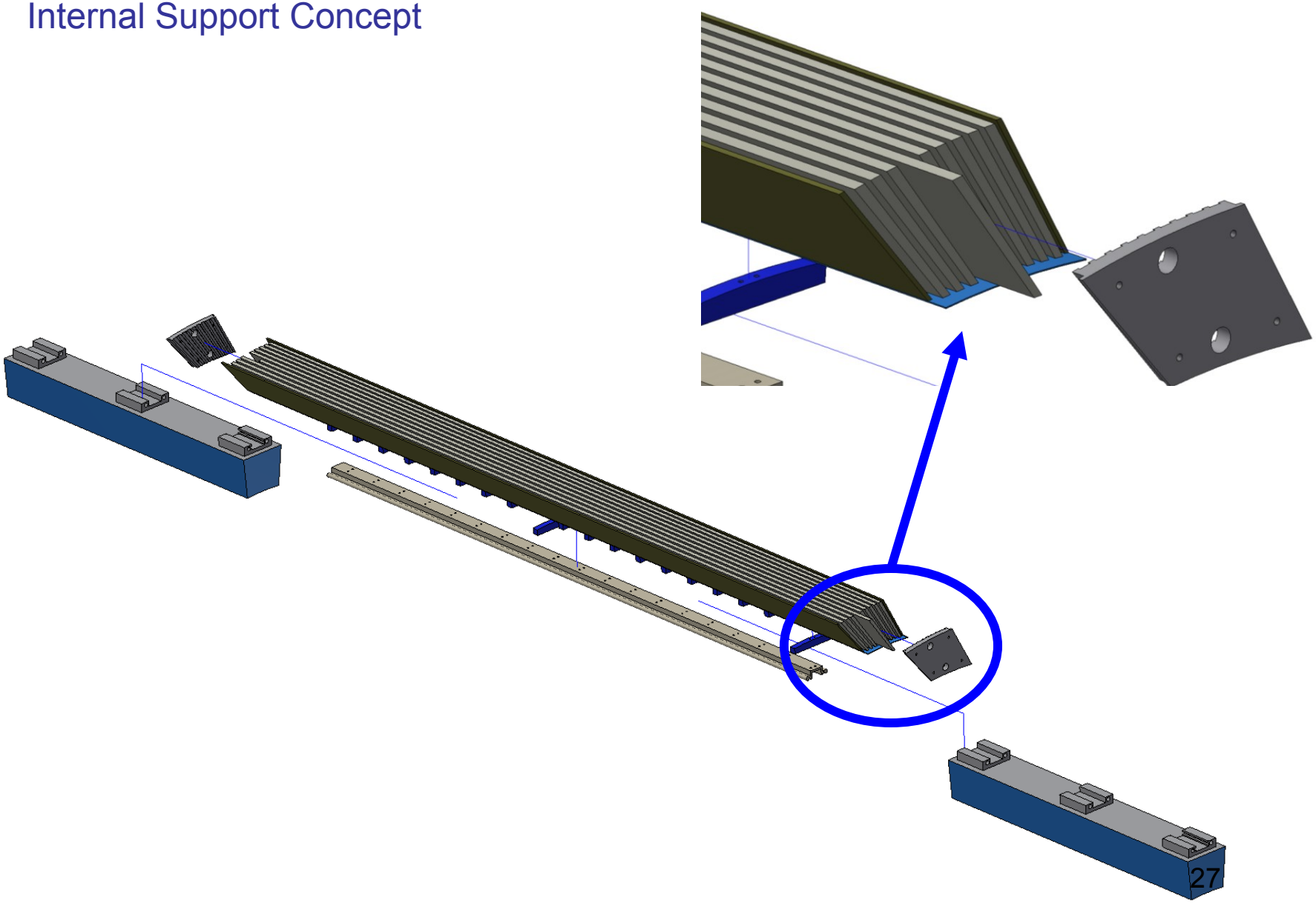
Inner HCal Exploded View

Internal Support Concept



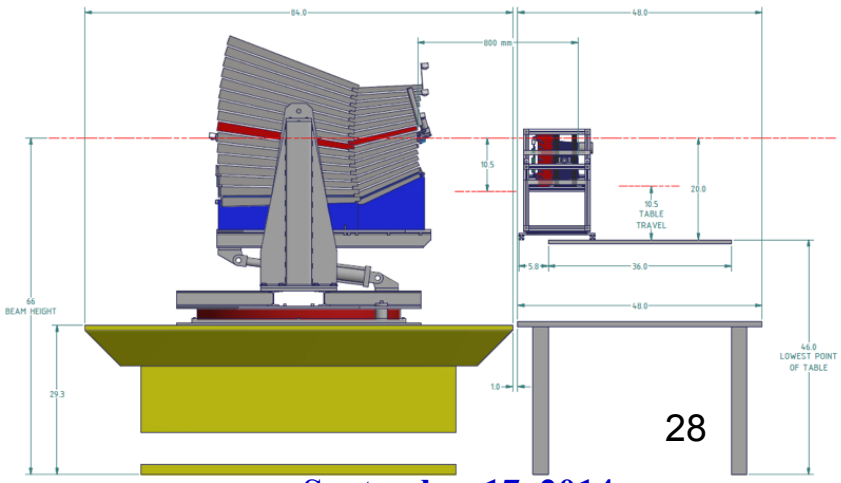
One Inner HCal Module

Internal Support Concept



R&D

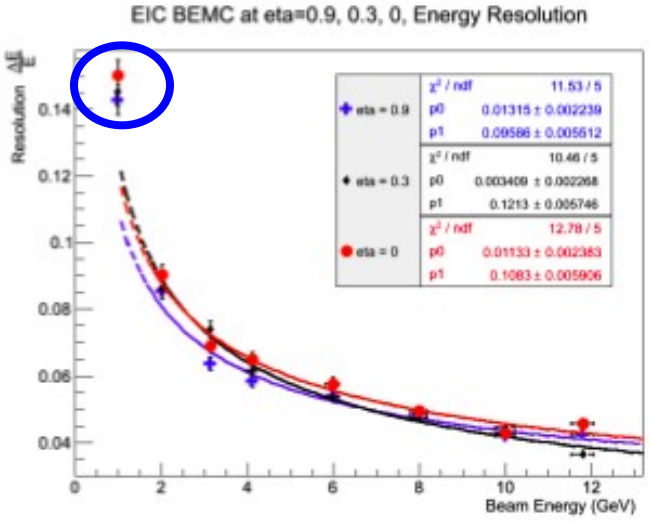
An R&D program for HCal, EMCal and electronics options is ongoing.
A number of tests took place in the FNAL test beam in 2014



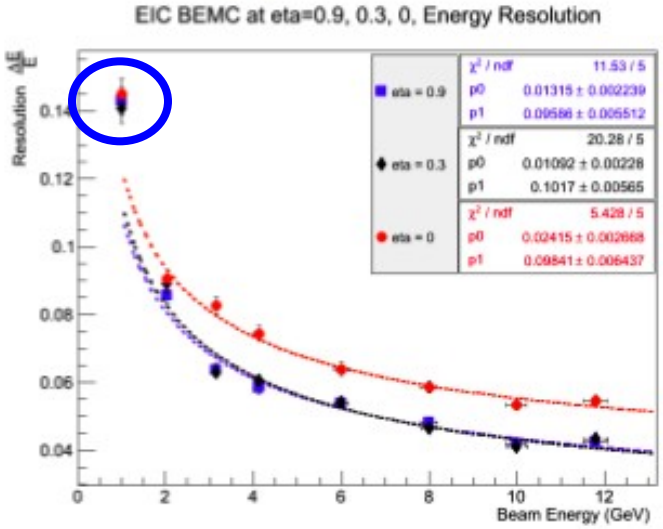
R&D - continued

EIC BEMC, prototype performance at FNAL. Preliminary Results.

ESR glued with silicone.



BC-620, painted at FNAL.



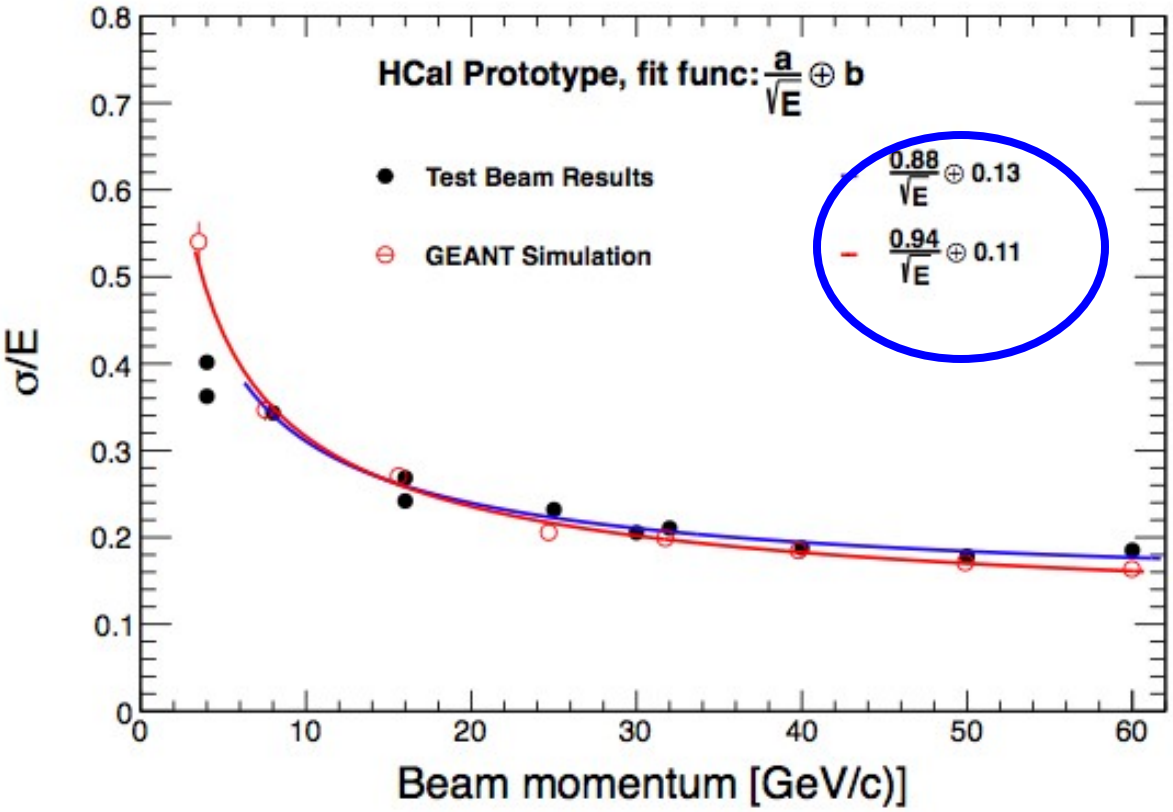
About the same energy resolution for 430 p.e./GeV and 530 p.e./GeV. In both cases at shallow impact angles it becomes better.

Giessen, CALOR2014,. April 10 2014

$\Delta E/E \sim 13\%/\sqrt{E} + \text{const}$

Oleg Tsai, CALOR2014

R&D - continued



Work continuing on analysis and simulation by Liang Xue (GSU) and Edward Kistenev

Project Preparation

- Cost, Schedule and Labor estimates
- WBS including Dictionary and Cost Book
- Conceptual Design Report
- Basis of Estimate documents
- Contingency Estimate – Bottoms up and risked based
- Project Execution Plan
- Safety and Hazard Analysis
- Quality Assurance Plan
- Acquisition Strategy
- Risk Analysis and Mitigation document
- National Environmental Policy Act document
- Integrated Project Management Team document

sPHENIX WBS

- 1.1 Project Management
- 1.2 Decommissioning
- 1.3 Magnet
- 1.4 Tracking
- 1.5 EM Calorimeter
- 1.6 Hadronic Calorimeter
- 1.7 Calorimeter Electronics
- 1.8 DAQ/Trigger
- 1.9 Infrastructure
- 1.10 Integration and Installation

WBS

WBS Number	Description	# Schedule Activities	# Cost Details	Contingency %	# Risk Assessments	# Supporting Docs	Responsible
1.05	**EMCAL**	**0**	**0**	**0**	**0**	**0**	**Woody/CAD Eng**
1.05.01	EMCal Design	0	0	0	0	0	Woody/CAD Eng
1.05.02	EMCal Prototype	0	0	0	0	0	Woody/CAD Eng
1.05.02.01	EMCal Prototype v1	0	0	0	0	0	Woody/CAD Eng
1.05.02.02	EMCal Prototype v2	0	0	0	0	0	Woody/CAD Eng
1.05.02.03	EMCal Preproduction prototype	0	0	0	0	0	Woody/CAD Eng
1.05.03	EMCal Production	0	0	0	0	0	Woody/CAD Eng
1.05.03.01	EMCal Module Production	0	0	0	0	0	Woody/CAD Eng
1.05.03.02	EMCal Module Assembly	0	0	0	0	0	Woody/CAD Eng
1.05.03.03	EMCal Module Testing/Calibration/Integration	0	0	0	0	0	Woody/CAD Eng
1.06	**HCAL**	**0**	**0**	**0**	**0**	**0**	**Kistenev**
1.06.01	Inner HCAL	0	0	0	0	0	Kistenev
1.06.01.01	Inner HCal Design	0	0	0	0	0	Kistenev
1.06.01.02	Inner HCal Prototype	0	0	0	0	0	Kistenev
1.06.01.02.01	Inner HCal Prototype v1	0	0	0	0	0	Kistenev
1.06.01.02.02	Inner HCal Prototype v2	0	0	0	0	0	Kistenev
1.06.01.02.03	Inner HCal Preproduction prototype	0	0	0	0	0	Kistenev
1.06.01.03	Inner HCal Production	0	0	0	0	0	Kistenev
1.06.01.03.01	Inner HCal Module Production	0	0	0	0	0	Kistenev
1.06.01.03.02	Inner HCal Module Assembly	0	0	0	0	0	Kistenev
1.06.01.03.03	Inner HCal Module Testing/Calibration/Integration	0	0	0	0	0	Kistenev
1.06.02	Outer HCAL	0	0	0	0	0	Kistenev
1.06.02.01	Outer HCal Design	0	0	0	0	0	Kistenev
1.06.02.02	Outer HCal Prototype	0	0	0	0	0	Kistenev
1.06.01.02.01	Outer HCal Prototype v1	0	0	0	0	0	Kistenev
1.06.01.02.02	Outer HCal Prototype v2	0	0	0	0	0	Kistenev
1.06.01.02.03	Outer HCal Preproduction prototype	0	0	0	0	0	Kistenev
1.06.02.03	Outer HCal Production	0	0	0	0	0	Kistenev
1.06.02.03.01	Outer HCal Module Production	0	0	0	0	0	Kistenev
1.06.02.03.02	Outer HCal Module Assembly	0	0	0	0	0	Kistenev
1.06.02.03.03	Outer HCal Module Testing/Calibration/Integration	0	0	0	0	0	Kistenev

WBS Task Activities - For Example

Schedule Activities

Add Schedule Activity

WBS Number: 1.06.01.02.01
WBS Description: Inner HCal Prototype v1

List all the Schedule Activities for this WBS element, in chronologic order.

Number	Activity	Duration	Start Date	Options
1	Steel plate design	30	10/01/2014	
2	Get quote on steel	10	11/01/2014	
3	Purchase steel	10	11/21/2014	
4	Tile design	60	11/01/2014	
5	Tile procurement	90	1/01/2015	
6	Assemble steel	60	2/01/2015	
7	Insert tiles into gaps	30	3/01/2015	
8	Design light collectors	30	1/01/2015	
9	Procure light collectors	30	2/01/2015	
10	Attach light collectors to tiles	60	3/01/2015	

Include Deleted Activities

Cost Details for this WBS Element
Supporting Documentation for this WBS Element
Risk for this WBS Element
Return to WBS

WBS Dictionary

1.07

Calorimeter Electronics

Responsible Person: 24903 - Eric Mannel

Dictionary: This WBS item included all electronics related to the EMCal and HCal readout from the Optical sensor(s) and associated electronics located on the detectors to the optical fibers and signal cables that connect to the PHENIX DAQ. It also included all electronics crates, power supplies and miscellaneous components needed for the detection of the optical signals from the Calorimeters through the digitization and transmission of the data to the DCM-II modules. The scope of the work includes system design and specification, prototyping, final design, fabrication, assembly and Q/A testing prior to full installation.

1.07.01

CalE Sensors

Responsible Person: 19796 - Sean Stoll

Dictionary: This WBS item covers the evaluation of optical sensors for the EMCal and HCal, defining specifications for the procurement of the selected optical sensor, oversight of the procurement of sensors, and testing and qualifying delivered sensors.

1.07.01.01

CalE Sensor Specification

Responsible Person: 19796 - Sean Stoll

Dictionary: This WBS item covers the evaluation potential optical sensors for both the EMCal and HCal detectors. Based on the evaluation of potential sensors, physics measurement requirements, and electrical and mechanical requirements define the specifications for the procurement of the optical sensors for both the EMCal and HCal.

1.07.01.02

CalE Sensor Procurement

Responsible Person: 19796 - Sean Stoll

Dictionary: This WBS item covers obtaining quotes, submitting purchase request and tracking delivery of the optical sensors for the EMCal and HCal using the sensor definitions developed in WBS item 1.07.01.01 needed for prototyping and full production of the EMCal and HCal detectors.

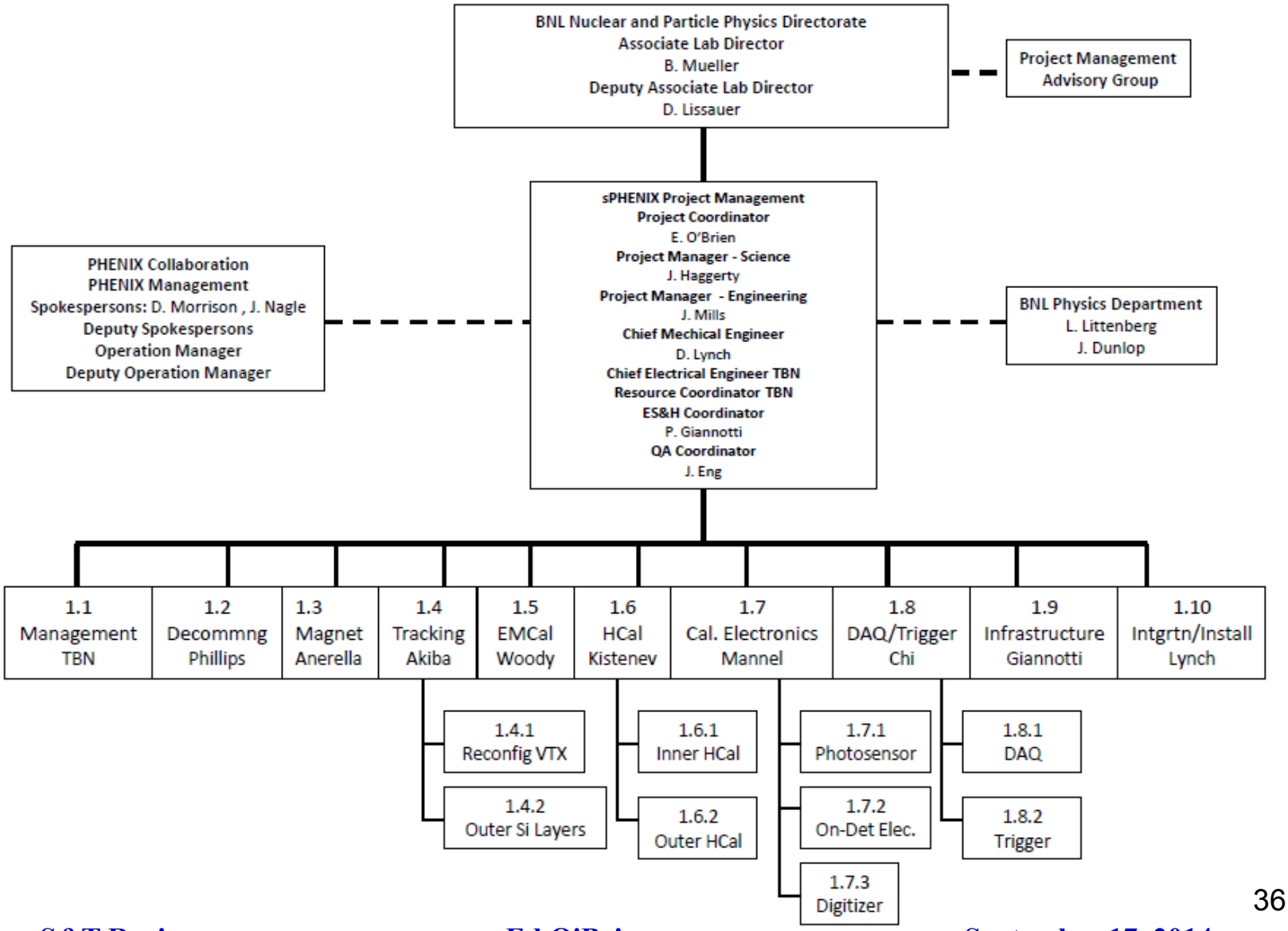
1.07.02

CalE On-Detector Electronics

Responsible Person: 20461 - Stephen Boose

Dictionary: The WBS item includes the oversight, design, prototyping, construction and installation of all electronics physically located on the EMCal and HCal detectors. This includes all printed circuit boards, power supplies, cabling (electrical and optical) from optical sensor to the Digitizers, and associated crates and mounting hardware.

Project Organization Chart



sPHENIX Status and Summary

- **Babar magnet is being prepped at SLAC for move to BNL.**
  - **Contract with the shipper is set. Only need to set the ship date**
  - **BNL/SLAC review of shipping procedures complete**
  - **BNL Magnet Division Team team at SLAC 1st week of September. Determination of final mods to shipping fixture.**
  - **Ship date will be determined as soon as the schedule for completing the fixture mods is set.**
  - **Expect BaBar solenoid at BNL within the next 4 weeks**

- **Space in 912 for magnet tests have been prepared by C-AD.**

- **Revised sPHENIX Proposal addressing recommendations of the Science review will be complete by the end of October.**

- **Progress on the sPHENIX reference design, physics/detector performance simulations, R&D and Project planning is continuing**

Back Up

sPHENIX Proposed Run Plan

Two years of physics running 2021 and 2022 with 30-cryo week runs

20 weeks Au+Au @ 200 GeV
10+ weeks p+p @ 200 GeV [comparable baseline statistics]
10+ weeks p+Au @ 200 GeV [comparable baseline/new physics stats]

sPHENIX maintains very high PHENIX DAQ rate
sPHENIX maintains fast detector capability – no pile up problems

If we just record Au+Au minimum bias events (no trigger bias), in 20 weeks with current RHIC performance and PHENIX livetime, we record 50 billion events within $|z| < 10$ cm [optimal for silicon tracking]

Note this is not sampled, but recorded. Full range of differential measurements and centralities with no trigger biases.

RHIC/sPHENIX Multi-year Schedule